

Lecture 23 - Limbic System

Limbic System (Nolte 5th Ed pp 559)

The limbic system is the name given to parts of the brain primarily concerned with: emotions, drive-related behaviour (sexually oriented), memory etc. The hypothalamus is involved in autonomic responses, which occur in response to emotions etc.

Hypothalamus (Nolte 5th Ed pp 561)

The hypothalamus is important in autonomic, endocrine, emotional and somatic function and is responsible for maintaining our internal environment within the normal physiological range (i.e.: homeostasis). The hypothalamus is located just medial to the lateral ventricle, forming part of the wall of the lateral ventricle.

Boundaries (Netter Plate 100, Fig 16-2, Fig 23-3B)

The inferior surface of the hypothalamus is directly exposed to the subarachnoid space, and is bounded by the mamillary bodies & optic chiasm. In a sagittal section – you are able to see the medial surface of the hypothalamus and from this other boundaries can be elicited. Superiorly bounded by the hypothalamic sulcus, anteriorly bounded by the lamina terminalis, and posteriorly bounded by the tegmentum of the midbrain. Lateral to the hypothalamus is the internal capsule (Fig 16-23) and medially is the third ventricle.

The hypothalamus can be subdivided longitudinally into anterior, tuberal & posterior regions. The anterior region is just above the optic chiasm, tuberal region is just above the tuber cinereum, posterior region just above mamillary bodies. In addition, the hypothalamus (of each side) is divided into medial (periventricular zone) and lateral zones. We know a lot about the medial zone (divided into nuclei) and the lateral zone – we just refer to it as a separate entity.

Functions (Nolte 5th Ed pp 562, Fig 23-4)

The lateral zone was not considered much at all in the lecture; except for that it is just a clump of nuclei interspersed. It is mainly involved in appetite and sleep regulation. The medial zone contains a number of nuclei. The medial and lateral zones are separated by the fornix. The supraoptic nucleus is located just next to the optic tract. The paraventricular nucleus is located more superiorly adjacent to the anterior commissure (Netter Plate 100). The axons of cell bodies located in these nuclei end up in the posterior pituitary. These nuclei secrete hormones: vasopressin (ADH - ↑ reabsorption of water in nephron) and oxytocin (induce uterine and mamillary smooth muscle contraction). The suprachiasmatic nucleus (just above optic chiasm) and the anterior nucleus are located in the supraoptic region. The former is involved in our circadian rhythms, and receives direct retinal input allowing it to adjust to the normal day length. Its neurons contain melatonin receptors, and melatonin released by the pineal gland during the night helps to “set” the circadian clock.

The preoptic area, ventromedian and arcuate nuclei (floor of third ventricle) all produce hormones that end up in the anterior pituitary.

Afferent and efferent connections are largely reciprocal (Nolte 5th Ed pp 564-568, Fig 23-6/8)

By reciprocal we mean, most of the pathways are two way.

Hypothalamic inputs (afferents)

Hypothalamic inputs arise from septal nuclei, hippocampus, amygdala, orbital cortex of frontal lobe, reticular formation + spinal cord & retina. Input from the amygdala is via 2 different routes: 1) stria terminalis, 2) ventral amygdalofugal pathway (Fig 23-6). The hippocampus outputs via the fornix which travels under the corpus callosum, through the hypothalamus, terminating in the mamillary body. We know the retinal ganglion cells send some processes to the suprachiasmatic nucleus (part of the medial hypothalamus). The orbital cortex of frontal lobe also sends input to hypothalamus. The septal nuclei project their input to the hypothalamus via the medial forebrain bundle.

Hypothalamic outputs (efferents)

The outputs from the hypothalamus are largely reciprocal to its input, hence involve outputs to: septal nuclei, hippocampus, amygdala, orbital cortex, brainstem and spinal cord. The pathways to these output terminations are the same as for the inputs. Other outputs are pure efferents such as: mamillothalamic tract, mamillogymental tract. The mamillothalamic tract projects from the mamillary bodies to the anterior nucleus of the thalamus. The mamillogymental tract is a branch of the mamillothalamic tract early on and this projects to the midbrain reticular formation and spinal cord.

Other major output from the hypothalamus includes the pituitary gland. This is probably the main function of all the output fibres. The supraoptic and paraventricular nucleus (discussed earlier) contain neurons that produce ADH & oxytocin. These hormones travel down the neuron's axons bound to a carrier protein → neurophysin. These axons terminate in the posterior pituitary – thus AP generation will release these hormones into the posterior pituitary. This is the neural control of the pituitary gland (neurohypophysis). There is also a vascular control of the pituitary gland (adenohypophysis) – Read pp 566 for more information.

Blood supply of the hypothalamus (Nolte 5th Ed pp 568)

Blood supply is derived from groups of branches of the Circle of Willis such as: anteromedial (preoptic + supraoptic areas), posteromedial (tuberal + mamillary bodies), anterolateral (lateral hypothalamus).

Limbic System (Nolte 5th Ed pp 569, Fig 23-10, Fig 3-11, Netter Plate 100)

The limbic system is concerned with drive-related and emotional behaviour, a substrate for emotions and feelings. The principal components of the limbic system include: cingulate and parahippocampal gyri, hippocampus (fornix – connects hippocampus to hypothalamus), amygdala, and septal nuclei.

The hippocampus is located on the medial surface of the temporal lobe. It is made up of three subsections: dentate gyrus, hippocampus proper & subiculum. The subiculum is the continuation of hippocampus proper (at one edge) and parahippocampal gyrus (at other edge). The major output from the hippocampus is the fornix, and the fimbriae represents the origin of the fornix from the hippocampus.

Papez Circuit (Nolte 5th Ed pp 576 Fig 23-16)

This is the simplest circuit, thanks to James Papez in 1937, that represents the interconnection between limbic structures, neocortex, & hypothalamus. Anterior thalamic nucleus → projects to cingulate gyrus → parahippocampal gyrus → entorhinal cortex (component of olfactory bulb) → hippocampus → projects through fornix → mamillary bodies → anterior thalamic nucleus to complete the loop.

Components of the Limbic System – A detailed perspective

Amygdala (Nolte 5th Ed pp 578, Fig 23-18 / 23-19 / 23-20)

The amygdala is a group of nuclei located anterior and superior to the inferior horn of the lateral ventricle. It is primarily associated with emotion of fear, but in total context it relates environmental stimuli → coordinated behaviour. It has a role in phobias.

Inputs to Amygdala (afferents) (Nolte 5th Ed pp 578 Fig 23-19)

The amygdala receives highly processed sensory information. This sensory information can be: somatosensory, visual, auditory & visceral. This input arises in various locations including: **hypothalamus, septal nuclei, thalamus**, orbital and cingulate cortex, olfactory bulb + olfactory cortex, **hippocampus, parabrachial nucleus**. Only learn the major ones highlighted.

Outputs to Amygdala (efferents) (Nolte 5th Ed pp 578 Fig 23-20)

Fibres exit the amygdala via two main pathways: 1) stria terminalis, 2) ventral amygdalofugal pathway. The stria terminalis arises in the temporal lobe and arches around towards the IV foramina paralleling the caudate nucleus and the terminal vein. The stria terminalis travels in the groove between the caudate nucleus and thalamus and its fibres distribute to the septal nuclei and hypothalamus. Its fibres also influence autonomic pathway structures such as:

paraaqueductal gray matter, parabrachial nucleus – involved in hyperventilation, parasympathetic dorsal motor nucleus of X, sympathetic preganglionic neurons in spinal cord.

The other pathway involves the ventral amygdalofugal pathway (Fig 23-21) which pass underneath the lentiform nucleus then distributing to base of brain.

Hippocampus (Nolte 5th Ed pp 570, Fig 23-12 / 23-13)

The fornix is the main output body of the hippocampus. The fimbria becomes the crus of the fornix, together called the crura. These merge along the midline to become the body of the fornix – which travels anteriorly at the inferior aspect of the septum pellucidum. At the IV foramina, it splits into two columns of the fornix.

Inputs to Hippocampus (afferents) (Nolte 5th Ed pp 574, Fig 23-14)

The hippocampus receives its input primarily from the entorhinal cortex. The entorhinal cortex receives input from cingulate, temporal, orbital cortices, amygdala and olfactory bulb. Some other inputs include: septal nuclei, hypothalamus, fibres from contralateral hippocampus via fornix, in the hippocampal commissure.

Outputs from Hippocampus (efferents) (Nolte 5th Ed pp 574, Fig 23-15)

The outputs from the hippocampus mainly arise from the subiculum and also some from the hippocampus proper. Many fibres travel retrograde back to the entorhinal cortex, and others travel to the amygdala. The main output is via the fornix. The fornix fibres arches under the corpus callosum, and at the level of the IV foramina the fibres split off in front of the anterior commissure (Fig 23-13) called: precommissural fornix. These fibres terminate in the septal, ventral striatum, orbital and cingulate cortex. Other fibres continue as the postcommissural fornix which end in the anterior thalamic nucleus, mamillary body. **Mamillary body degeneration** occurs in alcoholics which manifests as Wernicke-Korsakoff syndrome – where the intelligence is preserved but ability to form memories is impaired.

Memory function of hippocampal formation – Declarative memory (Nolte 5th Ed pp 576)

Declarative memory refers to the ability of one to remember events and facts clearly. The hippocampus has been associated with learning and memory. Bilateral removal of the hippocampus causes anterograde amnesia – cannot form new memories from the point of removal, while earlier memories are still intact. An example of it: when showed a red pen – the person is able to say it is a red pen (possibly from long term memory). But if the red pen is re-presented, and you ask: “remember seeing this pen just a few minutes” / they reply “no, I don’t – only from ages ago”.

Working memory/Procedural memory – is still intact. So a list of new numbers of a dictated phrase can still be retained, but this is lost at the first instant of any distraction offered to the person.

Interesting amnesia

Bilateral damage to the hippocampus affects short term memory – but it DOES not seem to affect learning memory. That is, a jigsaw puzzle can be re-assembled by a person with bilateral hippocampal damage time and time again – and each time – he/she get better at this skill. But, they may have no re-collection of seeing the puzzle before.